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ABSTRACT

Comparison is made between the techniques of research used in the physical sciences and those used in educational research, and the relative weakness of the reproducibility of educational research findings is noted. It is pointed out that while monitoring and feedback are essential in any research endeavor, they present difficulty in educational research because, by their very nature, they disrupt and degrade the processes of teaching and learning. An examination of Kline's theories on technoextension factors in relation to the extension of human capacity in the area of instructional capability leads to the suggestion that the computer can be utilized in these two necessary phases of educational research. (JD)

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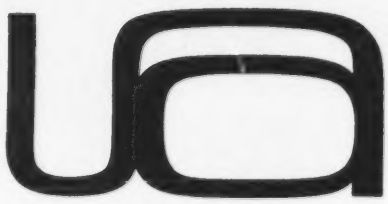

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PROSPECTIVES IN EDUCATIONAL RESEARCH

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Invited Address
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ABSTRACT

Educational research, in contrast to research in the physical sciences, has considerably weaker laws. Nevertheless, the importance of educational research which enhances a theory, or at least is supported by theory, is still basic to progress. In contrast to many areas of physical sciences where industry contributes considerably towards research, educational research is still primarily the domain of the faculties and colleges of education. Yet universities are currently subject to almost punitive budgets which are markedly affecting the progress of educational research. In addition the current fiscal policies of governments will reduce the number of bright graduate students who will enter the research field, and at the same time degrade the importance of research related to theory by offering research contracts to supplement inadequate budgets. Such conditions are not conducive to strengthening educational research.

The sequence of research, development, and dissemination, is considered to be incomplete without the element of monitoring and feedback. However, monitoring and feedback cannot be effectively carried out in the classroom without degrading the instructional processes. With reference to the work of Kline on technoextension factors, an attempt is made to estimate the curve representing the technoextension factor for instructional capability. Developments which have shown to have high technoextension factors, such as communication, arithmetic calculations, and fast access to memory, are considered to be important to increasing instructional capability. It is suggested that the computer, as an amplifier of intelligence and not as a tool, could serve the purpose of increasing mans instructional capability.

For many researchers prospectives in educational research may bring visions of the year 2000 when seemingly insurmountable problems of today are resolved with such finality that, in retrospect, one is awed by the simplicity of the solution. Do not most brilliant solutions when viewed in retrospect demonstrate the ordered simplicity of the world? Such dreams are easily nurtured by the giant strides which have been made in understanding the world about us, and amplified by the selective recall of our younger days.

Are advances in education to be made by shedding old approaches for the new as one might exchange an old coat for a new one? Will we be able to share the advances of other disciplines in the solution of our problems? Might the future hold a new calculus, or a new theory which would exort the alchemist and astrologer traits in each of us? Visions of advancement in educational research are likely to remain only idle dreams, excursions for coping with the real world problems of today, unless we reassess our present attitudes towards, reconfirm and where necessary expand upon, the processes by which we conduct educational research. It is my opinion that advances in educational research will be hard fought not only with those forces which govern our existence, but also amongst ourselves.

Few people would disagree with the dependency of future research upon the research carried out today, although less concensus would be obtained in defining what activities and paradigms might be labelled as research. The claim to research sometimes appears more dependent upon institutional requirements than upon the development of theory, testing its veridicality, exploring its generality, and searching for the boundaries of applicability. Although most of us would never openly

deny the importance of research in the development of theory, my first objective will be to re-declare the primary importance of research since it will continue to be the only basis for future advancements in education.[1] I shall point out what I believe to be a crucial missing element in educational research, particularly when laboratory results are moved towards the classroom. However, since it would be most difficult to implement the missing element, I shall propose how this difficulty might be overcome.

Traditionally, research has been primarily concerned with the development of theory expressed as functional and sometimes causal relationships among variables. In some fields, such as mathematics and in some segments of physics and chemistry, there may be little apparent relationship established among the parameters of a theory and the real world. In this regard, perhaps mathematics is most unique among the disciplines, although being entirely created by man, yet unlike most products of man, its boundaries are not known. Clearly, one can draw upon the advances of the physical sciences, acknowledge that research has provided the foundations for such advances, and then to infer that similar approaches must of necessity lead to advancements in education.

Drawing parallels between the advances in the physical sciences and potential advances in education is compelling. The development of laws, expressing more precisely the functional relationships specified by theory, have led to the building of internally consistent relational and logical networks. In the physical sciences early research gradually established the orderliness of nature on both micro and macro scales.

[1]This position is well illustrated for the physical sciences in the Illinois Institute of Technology report entitled "Technology in Retrospect and Critical Events in Science (TRACES). (National Science Foundation, Washington, D.C., 1969.)

The stability of such networks has been supported by the apparent recurrence of communality in nature whether on earth or in space, in atoms or in solar systems.

But the development of theory has not concentrated solely upon the search for orderliness in nature. When such appeared not to be the case, research, particularly in mathematics, lead to the development of theory specifically designed to account for the disorderly behavior of elements and events in nature. Thus, where randomness was suspected, theory led to laws which were idealized for a multitude of behaving and interacting units as in molecular motion.

In retrospect, it is relatively easy to see that order has been built upon order, that old giants shoulder the new giants, and that the proliferation is not so much a stable pyramid but rather a series of inverted pyramids. The importance of developing theory as the foundation for understanding nature can, with the application of some sensitivity and thought, which is not always evidenced in the benefactors, be supported by developments in chemistry, biochemistry, physics, genetics, and medicine.

Of course it is easy to look back upon the developments in the sciences which have been successful and to attribute these successes to only those critical explorations which were the basic stepping stones toward such success, and to discard the competing explorations. There is no doubt that a crucial factor in developing the high degree of reproducibility and stability, which characterizes the results of research in the physical sciences, has been the ability to concentrate effort upon definable and relatively homogeneous elements of nature, and so effect a high degree of control over the experimental environment.

Homogeneous elements and a high degree of control are, of course, not characteristics which can become part of research in education. This does not, however, deny the primary importance of research, it only changes the conditions under which we must operate.

Although today a considerable amount of research is conducted in private laboratories, particularly by companies which see future profits as being based upon today's research, the university still forms the primary environment for much research. Certainly, it is within the university structure that educational research is most frequently found. Within this environment there are a number of obligations which exist by specific design or because of the collective history of the various faculties and departments. Clearly, one obligation is to teach and train teachers, while the second obligation is to conduct research. In addition to these two obligations, which have varying importance for different groups, there is professional service to the community and to participate in the administrative functions of the university.

Moving education from the normal school to the university required that we embrace as best we could the obligations of the university community with regards to research, not only to increase our credibility but also to increase the quality of teacher training. But, while other disciplines and professions had already established much of their modus operandi with regards to ensuring a place for research, education has had to concentrate upon this direction in the context of increasing enrollments, a lack of well trained researchers, and a depression mentality with regards to research funding. Although expectations were that these conditions would gradually change by a stabilization of enrollments which would provide time for research, and the provision of

funds to establish the basis of both human and capital resources, this of course has not come about. Instead, the leveling off of enrollment under present fiscal parameters has led to a decrease in financing which some have described as punitive financing. Of course a stabilization of enrollments and budgets cannot be considered to be the only factors which have affected the ability of educational research to move forward. As enrollments grew, universities were prepared to 'be everything to everybody' who wished to come. The college system had not yet been developed to provide for the legitimate needs of many students. Indeed, economic conditions suddenly made for a 'surplus' of university graduates in some areas, and the attitude of the politician and some publics changed with regard to the importance of the university. Perhaps what really happened was that misconceptions of the primary role and place of the university were suddenly made clear, and jolted those whose only interest was training for a job.

Instead of developing fiscal policies which would, for example, allow teaching overloads in one period to be balanced by more research time in another period, governments in the provinces have taken short ranged views of society's long standing problems in education. The last six years brought about conceptions of educational research distorted by the need to provide immediate answers, political and financial accountability, and for training programs to provide the basis of promotion rather than knowledge with sufficient generality and applicability to solve educational problems. Increasingly we are being seduced by the offering of contracts for the production of information and data, and this seduction is encouraged by the pressure to ameliorate the effects of budgets inadequate to cover inflationary trends. Too frequently these contracts

reflect what Suppes (1974) has called "bare empiricism" and equated with "mental streaking, — a nudity of mind which is less appealing than nudity of body." Bureaucrats, some being our own students who have missed or forgotten that the primary purpose of basic and applied research is to provide for the development and enhancement of theory, and who have also forgotten that the knowledge they gained while at university was not produced by the simple procedure of finding someone else's work in an automated retrieval system, are 'calling the shots' and ignoring the conditions for research by demanding that creativity be interred in block diagrams of the systems approach. The amount of time necessary to gather together the components for a moon-shot may well be expressed in man-months, but the creative research required to describe the relationship between a moving body in space and a planet in the solar system was not.

The most serious problem, although directly related to funding, is not however, receiving due attention. Universities possess a number of staff members who are unproductive in research, and a number who will grow old and become less productive. When these factors are coupled with almost no staff mobility there is little chance for young bright people to join the university. In fact these conditions are discouraging potential students from entering careers in research. The long run projection of this situation is clearly alarming. The whole university system, with all its faults, but which still provides the opportunity for the creation of ideas, could well approach a state of rigor mortis, and society as we know it today would follow. We must never forget that as a society we are only two generations away from the dark ages and that it is only an educational system, including the universities, which

protects us from the scourges and medieval practices of the past.

These problems, however serious, should not detract us from maintaining our sights upon research which has theoretical significance. Twelve years ago Cronbach sounded the warnings of being detracted from this goal. In speaking about large educational dissemination projects, which today may be considered to have been replaced by large contracts, he noted that

> "...the hidden cost of the gift is too great, if it turns the experienced researcher into an administrator sitting atop a vast machine that grinds out normal science in which the data are untouched by the human mind."

Cronbach also noted that

> "...what counts is the jump in which a radical mind asks a new kind of question. In education as in other fields normal science is not enough. We must maximize the likelihood of scientific revolution."

Twelve years after Cronbach's warning, Kerlinger (1977) restated in a much stronger fashion, the need for maintaining our focus directly upon educational research with theoretical significance. Although many may disagree with some of his strong statements concerning the social utility of educational research (Slavin, 1977), one cannot disagree when he noted that "research that is not excellent has no place in science", and that in order to train researchers we must

> "...give (them the) best theoretical, mathematical, and methodological training possible in order to maximize excellence. Conceptual and technical competence should be our first training goal."

Perhaps we do ask our students to read theoretically-based educational research, and to note the origins of such work, but do we require them to think in a theoretical manner? Thinking and creating in the theoretical domain involves not only the specialized understandings of the

primary discipline, but also at least a broad understanding of related disciplines. Theoretical explorations involve being sensitive to the real world as well as knowing how to build models to describe functional relationships. Clearly, methodological and mathematical training is necessary not only as a basis for deciding what work of others is valid and to recognize results of analyses which are highly confounded with arithmetic artifacts, but also as a basis upon which extrapolations can be made of a theory. What must be prevented is the unwarranted generation of pseudo-theories which cause too many of our graduate students to chase after rainbows. Although the nurturing of such giants in the physical sciences as Fermi, Rutherford, and Einstein may be in part fortuitous events, this should not detract us from examining the excellence of our graduate training programs. Are we getting so myopic that in training of reading specialists we excuse them from understanding, not just basic arithmetic, but also calculus? Do we rationalize the absence of educational foundations in the training of measurement researchers by claiming that they do know calculus? Have we substituted the black box of the computer for an understanding of mathematical statistics?

In a recent report entitled the Fundamental Research and the Process of Education, submitted to the National Institute of Education by Kiesler and Turner, not only has the importance of educational research been restated, but those factors believed to enhance research have also been noted. Firstly, there must be an atmosphere were criticism can flourish in the open. For a beginning or hesitant researcher, this may be slightly traumatic, but it can be alleviated by publishing research reports within one's own institution. Hopefully, this

experience with such small beginnings will lead to more substantial publications. Secondly, expertise in research is essential and is not brought about by simply being familiar with a research area. We should not talk about research studies, but rather, research programs. Research programs take five to ten years to develop; they cannot be created overnight by administrative fiat. A research program is not a sequence of events dependent upon the successful awarding of a government contract which purchases answers to questions asked by someone else. A research program is like life itself, taking many years of nurturing before maturity is reached, however, like life it may be destroyed in a fraction of a second, or worse it may be tortured to death by slowly removing its nurturing sustenance. The same report also noted the importance of time, openness, and flexibility. Excellent research does not take place in the rush of deadlines for reports, nor does excellent research come about through the blind adherence to rigid specifications of research design. Speed may be fine when one knows precisely where the research is to go, but explorations and creative synthesis cannot be governed by time. Unfortunately, some agencies in need of research results have extrapolated the results of one man working for ten years as equivalent to ten men working for one year. Such an approach to educational research is simply ridiculous. On the other hand, the researcher is obligated to make a careful and continuous distinction between creativity and chaos regardless of whether working in basic or applied research.

Only a naive person can deny the tremendous advancements which have been made through research. Hard sciences make more than a "just noticeable difference" each year in their progress. Cronbach has suggested that research development, and dissemination are necessary to

keep the educational system moving forward. But is this enough? Do we honestly believe that more theoretical work upon which applied research and development is based will satisfy our own needs as well as those of the educational system? Although we may seldom think of our own research as inconsequential, few can deny the existence of doubts about the research of our colleagues. Although the model of research, development, and dissemination may have worked exceedingly well for the physical sciences, is there good reason to believe that it will work without modification in educational research? It may not be self evident that research, development, and dissemination is sufficient for education. The hard sciences are characterized by having stronger laws in the sense of predictability, as well as having a greater reproducibility given a set of known conditions. The laws are stronger even when probabilistic events need to be taken into account. Unfortunately, such is not the case in educational research. Not only are our laws considerably weaker, and not subject to easy verification, but we may be unknowingly attempting to capitalize upon, and perpetuate the belief in, events which are only statistical artifacts.

How well has applied research and development worked in education? Commercial firms and government agencies directly encourage the development of applications involving scientific principles. Clear examples of such efforts are observed in the fields of atomic energy and in the development of computers. But where is development to be carried out in education? Faculties of education were established with the primary objective of providing teacher training and not development. Seldom, in Canada at least, has the development component in a faculty of education been a primary objective. If one examines the many materials

used in the classroom, one will find that they have been produced with little prior development work. Perhaps because of this reason, few materials and procedures are based upon, or at least clearly reflect, a theoretical approach based upon learning theory.

The point which must be made is that the one-way street of research development and dissemination which has worked so well for the physical sciences is not sufficient for education. Our principles are far too weak, our reproducibility far too low to have a uni-directional sequence of research, development and dissemination. The most crucial factor which is missing, and which must be present in educational research is the capability to increase the strength of our principles and reproducibility of results. The demand for this capability is complicated by the ever changing nature of our students, whether by development, or by environment, and because our system of delivering instruction must be totally dependent upon the human teacher.

The crucial factor which is missing in the research sequence is monitoring and feedback to correct basic theory, and to refine and tune our procedures and materials at the development stage. I believe that as researchers we are behaving in a very presumptuous and naive manner to think that research, development, and dissemination are sufficient either to enhance our theories, or to effect that kind of development and dissemination which will lead to a better control of our educational problems. Researchers seem to be most cognizant of the need for monitoring, but the research environment is too restrictive, when compared to the classroom environment, to assume that what works in one will work well in the other. Development must have its monitoring carried out in the classroom where it is important to be sensitive to the need for

correction before too much time is lost, or before errors are no longer correctable.

Parameters of the monitoring process have been developed under the traditional title of measurement and evaluation, and there is little need for these to be reviewed. There are, however, two parameters which have been generally ignored. One important parameter associated with monitoring is the rate at which monitoring takes place, while the second parameter is the element or unit which is being monitored. There is no question that both rate of monitoring, and the selection of the element to be monitored are highly dependent upon the capabilities of the monitoring system. In the first case, for example, it is absurd to monitor those factors related to weather prediction on a weekly basis if serious consequences due to the weather can occur within the time frame of one day. For similar reasons, it is useless to monitor the averaged parameters of several weather systems in an attempt to determine the specific effect for a given geographical area.

Firstly, consideration must be given to the rate parameter of the monitoring systems employed in education. Traditionally, we have implemented monitoring programs with widely different monitoring rates; royal commissions every five to ten years, yearly examinations, mid-term examinations, class quizzes, the question and answer interaction between a teacher and a pupil, as well as the rapid observational monitoring by the teacher of behavior directly related to learning, such as the attentiveness of students. In these examples, the rate of monitoring is extremely variable, and the nature of what is being measured also varies. Secondly, for each of the above monitoring modes which have been ordered by the rate of the monitoring process, it is also important to consider

the unit or element being monitored. At one extreme exists monitoring which provides aggregate data over large groups such as produced by province-wide examinations, and at the other extreme, the continuous monitoring of a single student in the process of learning.

Regardless whether learning is considered to be continuous or to follow some type of step function, learning progress is best identified by those methods of monitoring which are fast and which are made on each individual learner. Monitoring of individual progress taken over short periods of time are desirable because errors can be detected early, and such data can be, if needed, aggregated to calculate other more gross parameters. Furthermore, errors can be more directly related to instructional content and procedures used at a specific point in time.

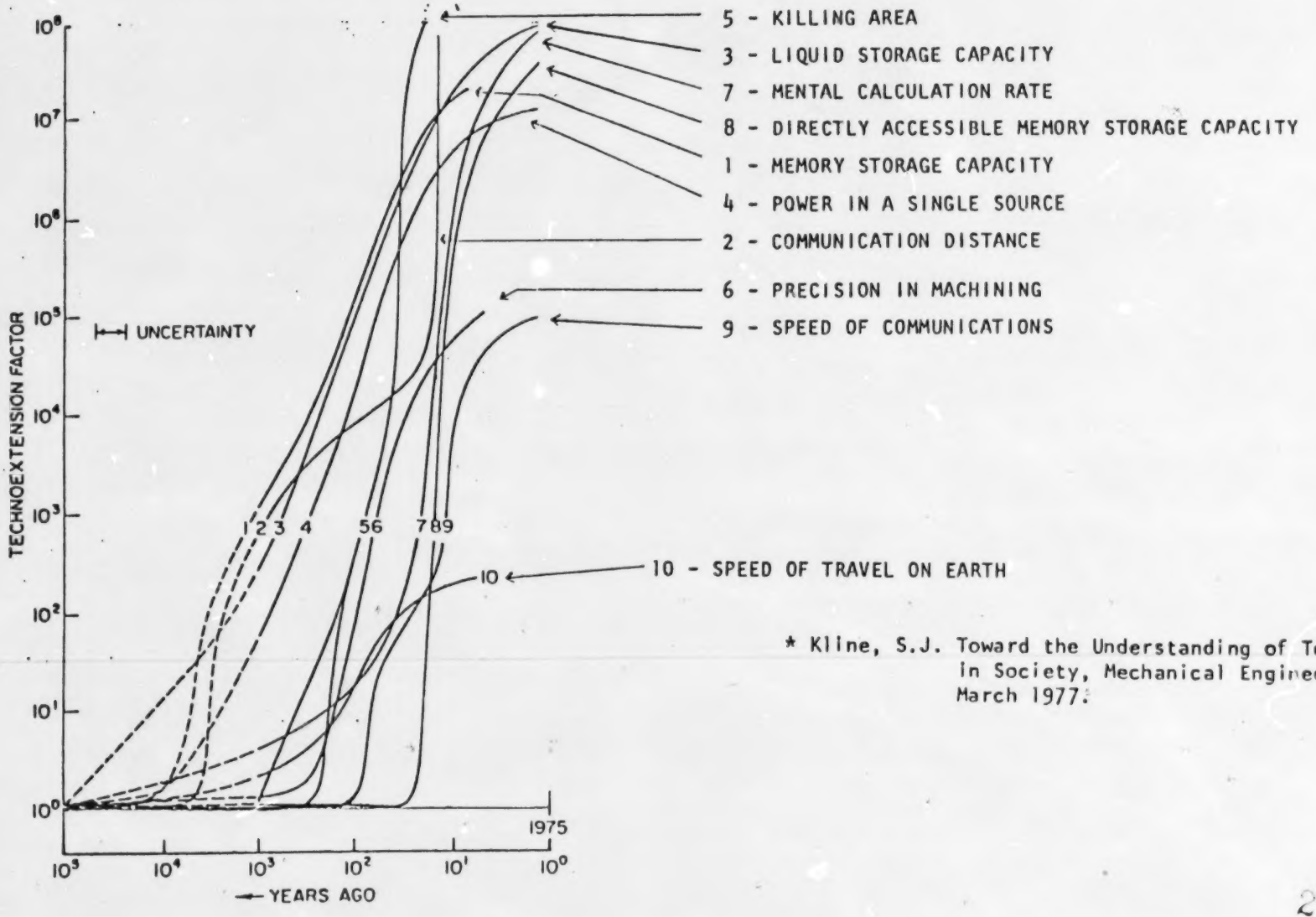
In the typical classroom the fastest monitoring can be made by the teacher's observational talents as interaction between teacher and student takes place. However, even though this monitoring is rapid, it can only provide a monitoring of a single student. The observational monitoring of other students can only be made of such factors as attentiveness to the instructional activity. In addition, the monitoring can only be time based, i.e., sequential or continuous, if the teacher maintains the interaction with one student and ignores the monitoring of the other students. On the other hand, if the time base for monitoring a single student is sacrificed in order to monitor other students, the continuity of monitoring is lost. Interaction analyses of teacher-student behaviors attempt to get around the problem with video tapes which allow the monitoring of students other than the one interacting with the teacher. However, this provides no solution, because the nature of the interaction of non-participating students cannot be equated with

the single participant. Unless a single tutor was provided each student, it is humanly impossible to effect a high rate of continuous monitoring for all students. The implementation of more formal monitoring procedures, such as daily quizzes to effect a more rapid rate of monitoring would result in an intrusion on the instructional activities of the classroom, such that the instruction would be degraded. If monitoring is to be maintained at a rapid and continuous rate with each learner, then it must not degrade the instructional and learning activities of the classroom. More simply, monitoring must be unobtrusive and non-degrading of the instructional activities.

With due respect to the best teachers in our classroom, and recognizing the instructional activities which teachers are expected to carry out, it would seem hopeless to implement monitoring procedures having characteristics just described. For in addition to the monitoring of learning, the teacher is asked to plan and execute a lesson which embodies both the logical and psychological ordering of curricula, to make deliberate use of principles of learning and motivation, all of which must be commensurate with the development, both cognitive and psychological, of the child. These activities are expected to be carried out in classrooms with due recognition of the individuality of twenty or thirty children on a daily, weekly, and monthly basis. This request borders closely upon being humanly impossible to meet and, when extrapolated to the classroom, can only lead one to conclude that the instructional environment of the classroom must be degraded until it is acceptable to the teacher, the child, and on some occasions to the parents. Short of having super-human powers, how might all the instructional activities, including the monitoring, be carried out? Surely we

TECHNOEXTENSION FACTORS ESTIMATED

BY KLINE


5 - KILLING AREA
3 - LIQUID STORAGE CAPACITY
7 - MENTAL CALCULATION RATE
8 - DIRECTLY ACCESSIBLE MEMORY STORAGE CAPACITY
1 - MEMORY STORAGE CAPACITY
4 - POWER IN A SINGLE SOURCE
2 - COMMUNICATION DISTANCE
6 - PRECISION IN MACHINING
9 - SPEED OF COMMUNICATIONS
10 - SPEED OF TRAVEL ON EARTH
UNCERTAINTY
TECHNOEXTENSION FACTOR
YEARS AGO
1975
1 2 3 4 5 6 7 8 9
10

* Kline, S.J. Toward the Understanding of Technology in Society, Mechanical Engineering, March 1977.

cannot expect genetic changes either in the student or in the teachers, although one cannot deny the possibilities of geniuses among us, their numbers are insufficient to make any appreciable and direct impact upon the problem.

The extension of human capabilities has been rapidly increasing during the last century, and a measure of this extension has been reported by Stephen Kline of Stanford University, during his acceptance of an award in fluid engineering. This measure of extension is called the 'technoextension factor' and is an estimate of the ratio formed by the increased human capacity due to technical aid to that of the unaided human capacity. The estimation of these ratios or extension factors is made to show, for example, the increased human capability brought about by the mechanical advantages of machines relative to that of the unaided human muscles, the lens both optical and electronic to extend human vision, the use of books, records, and magnetic tapes to extend the human memory capacity, and the use of radio waves to extend the capacity for communication. Thus, for example, if the electron microscope provides a magnification factor of one million times over that of the unaided eye, the technoextension factor would be taken as 10^6 to 1, or simply one million.

(FIGURE I HERE)

Figure I shows the technoextension factors estimated by Kline for memory storage capacity, communication distance, liquid storage capacity, power in a single source, killing area, precision machining, calculation rate, direct access memory capacity, communication speed, and the speed of travel on the earth's surface. In reading the graphs one must keep in mind that the axes are scaled in logarithmic units. It is interesting

to note that extremely high slopes exist for such capabilities as killing area, calculation rate, direct access memory capacity, and communication distance.

In order to highlight the need for extending our human capabilities in the area of monitoring and instruction, it is useful to estimate the extent to which instructional capability has increased over the same time period used by Kline. Admittedly, this is not a simple task since it is confounded by the capacities of the learner, the teacher and our understanding of the learning process. In my thinking about the problem I have concluded that the basic capacities of the teacher, as it might relate to the estimation of technoextension factors, falls into a category of communication, and that this communication is basically limited to oral communication, and physical movements. These are constraints placed upon the human condition. Crucial to instruction is, of course, that the communication must be of a specific nature, ordered by content in time. It seems to me that the purpose of this communication is to have information stored by the student, to provide the student with the capability of communication, and most importantly to formulate and support these capabilities through the generation of thought processes. These thought processes may involve the recognition and input of external communications and the generation of other thought processes. These same capabilities and activities, hopefully to a greater extent, are also characteristic of the teacher. In the context of instruction, one must always note that communication is not instruction, but instruction does involve communication. Communication, to be useful for purposes of instruction, must have a specific ordering and organization of content to bring about learning in a student. In

addition, the circumstances surrounding the teacher and the student, which include a host of psychological variables, must not be ignored. Although psychological variables may be enhanced through technological factors, such as for example, increasing motivation by the introduction of physical elements into the instructional environment, there is still a large domain of activities which involve only interpersonal conditions.

Setting aside, but not denying for the moment, those factors which can only be defined in terms of human capacity, the problem is to estimate the technoextension factor for instructional capability and to estimate its position and form relative to some of the factors which Kline has graphed. For this purpose, I have defined a unit instructional capability as the capacity of the unaided teacher to bring about learning in a majority of students, excluding those students having physical impairments of the nervous system. In taking the most general liberties in seeking the basic elements to instruction in order to be able to place a curve of instructional capability into position among Kline's extended capabilities, three capabilities seem most basic: the generation of information (the thought process of the teacher), the storage of information, and communication. In order to even make a crude estimate of where the relative position of instructional capability might fall in Figure 1, the clearest technical extensions which appear related to instruction, are communications and storage of information. In the educational context, communication can be supported by such technical aids as amplifiers, books, audio visual devices, and the use of signals such as those employed in radio and television. However, it is inescapable that when one considers technical aids to communication, two conditions immediately become evident. Communication may be in real-time, that

is, as it happens, or, that communication involves the storage of information and its later reconstruction. Thus, a very large number of technological devices involved with communication also have, inherent to their design, the capacity to store information. Therefore, in the context of Kline's curves, one important reference point must be taken to be direct access memory. Storage capacity itself, although showing remarkable growth, is not as important because, as time goes on, in instruction the need to have rapid access to stored information is an important factor.

Another reference point among Kline's curves, which seem reasonable to use to help identify the position of the curve for instructional capability, is calculation rate. Although one might envisage only simple arithmetic manipulations, the same rates apply to making very elementary logical and relational decisions. But the high rates of calculation which have been achieved, could not have been obtained by a human deciding upon the calculation steps in real-time. However, with the storage of the steps necessary to effect a calculation, the limitation of human input speed is removed. But, this suggests again the importance of direct access memory capability which also was found important in communication. Calculation rate and direct access memory speed and capacity have an important bearing upon communication, for the combination of the two provide the basis for capturing and re-creating a wide range of differing phenomena. For example, the combination of calculation rate and memory provide the capability to communicate three dimensional orthographic projections, complex drawings, photographs in static or dynamic form, and even to recognize human speech and to simulate human speaking. Although some may believe that technical

systems for the recognition and simulation of human speech are purely speculative, the systems, although crude by human standards, are already available on the commercial market and the development rate is accelerating due to tremendous increases now possible in calculation rates and memory capacity.

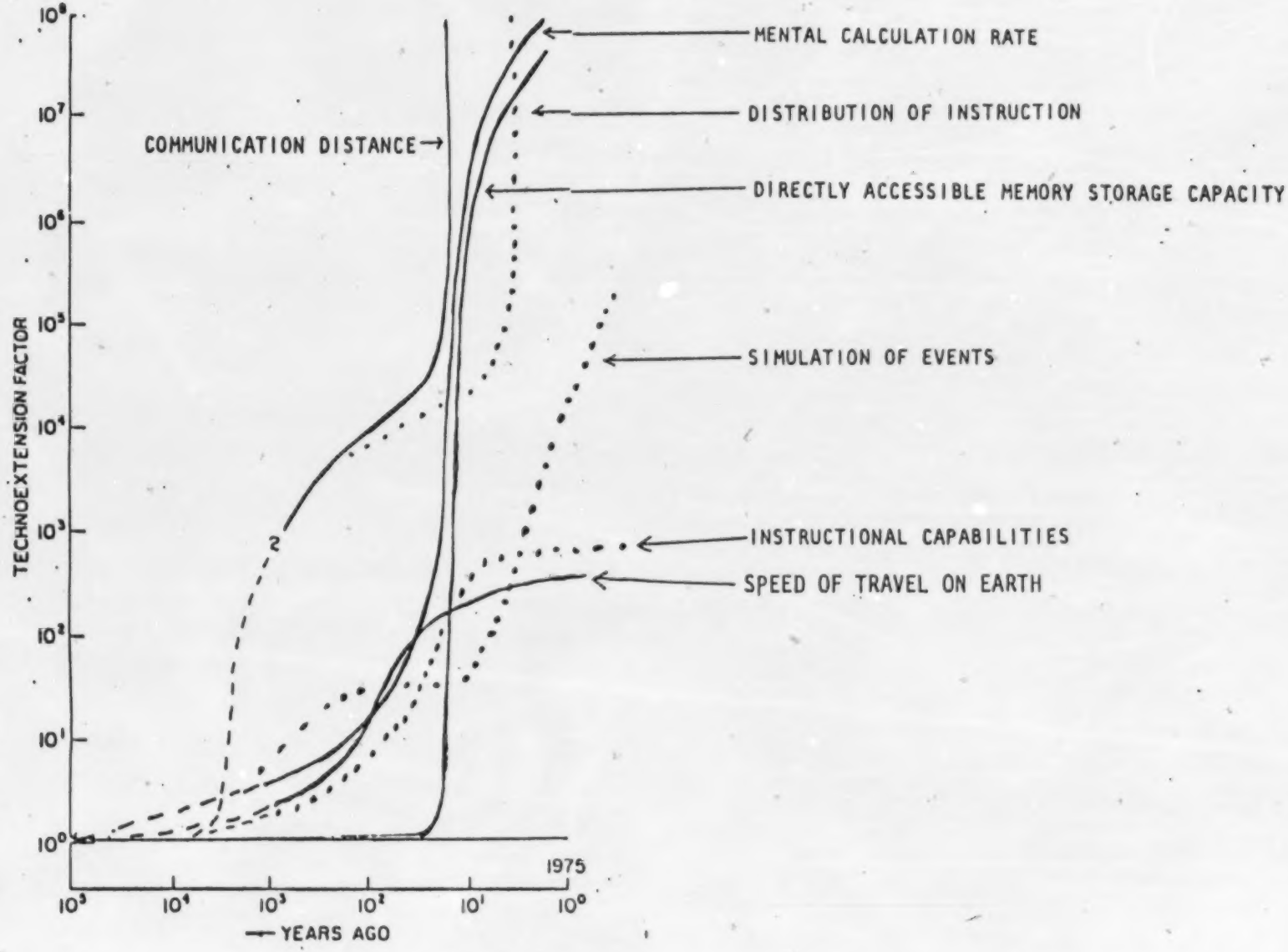
The generation of thought processes, a vital component in the human condition, whether it be for the teacher or the student, is a far more difficult attribute to relate to technological factors. The same factors which are vital to communication, that is memory access speed and capacity, and calculating rate are also important in the generation of thought processes, but only if the information stored includes the precise definition of the strategies from which super-rules can be formed and acted upon. Investigations are being made in this area under the term of artificial intelligence. One has to admit, the curve expressing the rate of this factor is limited, for now we must recognize a tautology where design parameters must be first defined by humans to provide humans with further information and knowledge through communications.

Trying to take into account all of the general factors I have noted, and relating these to specific effects of various technological developments, Figure II illustrates my estimate of the technoextension factor for instructional capability.

(FIGURE II HERE)

I have also estimated some other curves against which instructional capability can be judged. There is no question that the distribution of instruction tends to follow the high slope of curves typical of Kline's study. The distribution of instruction has been markedly

TECHNOEXTENSION FACTORS ESTIMATED FOR SOME INSTRUCTIONAL ACTIVITIES



enhanced by the distances over which we can communicate through the use of such developments as radio and television. I would argue, however, that we are now able to distribute a suboptimal level of instruction over wider areas. Because simulation, or the recreation of events is dependent upon direct access memory and calculating power, it also has a very high slope. Simulation capability has only a marginal effect on instructional capability because of a low rate of utilization.

Now one might wish to argue that those factors which have shown very high rates of technoextension factors are clearly the product of the human mind, and that surely this must reflect upon the instructional capabilities we have developed in society. Although there may be an element of truth in this position, it is not a compelling argument, for the progress made in these rapidly developing endeavors represents the accumulation of theory, research, and development by admittedly, bright and sometimes genius-like individuals, in itself this does not demonstrate an application of our instructional capabilities within the educational system.

One might also argue that the curve I have estimated must of necessity be reaching an asymptote, for instructional capability can only be judged in the context of the learner, and clearly genetic changes do not occur sufficiently fast to improve upon the instructor-learner interaction. I would accept this as a reason for the curve having such a small rate of change, and would also argue that this reason is the basis for determining how the slope for the curve might be altered. Indeed, one might view with alarm the importance of not changing the slope in view of the slope of the other curves Kline has estimated, particularly the killing area.

The question may now be asked, "What is the relationship between monitoring and technoextension factors in the context of instruction"? I have taken the position that research is of crucial importance to the eventual amelioration of problems in education, and that there must be a monitoring component added to the research, development, dissemination phase. In addition, I have argued that the type of monitoring which is most important must be fast, unobtrusive, and non-degrading of the instructional activities in the classroom. When these monitoring needs are coupled with the demands already placed upon the teacher, and since I have suggested that a humanly impossible task already exists for the classroom teacher, then the result can only be a further degradation of the teaching-learning process. Since we cannot expect a major amelioration to be brought about by genetic changes either in the teacher or in the student, we must seek other means of breaking away from the asymptotic state. If technological advances are to be used as the basis for escaping from the present state then, based upon Kline's work, utilization of those technological factors related to calculation capacity and storage of directly accessible information would seem to be most relevant. These two capabilities have very high technoextension factors and appear related to needs of instruction. In addition, they are also related to the basic processes of monitoring. There is only one technological development having functions capable of fulfilling these requirements. This device is the computer.

Before the word computer causes too many educational researchers to raise objections by citing their inaccurate computer billings, I would note some of the examples of computer applications to educational research problems related to reading given by Kiesler and Turner in

their report to the National Institute of Education:

> "The new cognitive processing approach, in theory and method, is very unlike that taken in the studies of nonsense syllable learning that were common twenty years ago. Researchers employ new mathematical techniques, computer simulations, and research designs."
>
> "That much progress has been made in the last ten years, however, is quite clear from the success researchers have had in roughly simulating human thinking. A few years ago, for example, researchers at Carnegie-Mellon University demonstrated that a very simple computer program, using perceptual processes already employed in computer chess programs, moves its attention about the board in a way that resembles the eye movements of a human chess expert."
>
> "Finally, there is research on artificial intelligence that involves the development of computer models of knowledge structures, the efficient retrieval of information, and adaptable systems capable of learning, understanding, and producing natural language. Work on each of these topics is aimed at increasing the understanding of how the human mind works and how mental skills, such as reading, might be more easily acquired and refined."

Since the computer has been categorized as a tool by many people, I must first caution those taking this position that they are very much in error. In the most general sense, a tool provides the user with a mechanical advantage and may employ mechanical principles which also alter the direction of forces. Early tools were crude and human powered, the user determining the nature of the action and the rate. More complex tools may still be characterized by providing mechanical advantages, but tend to have their own sources of power rather than depending upon that of the user. Some of the more complex tools require the worker to adapt his working rhythm to that of the machine, e.g., an assembly line. A computer cannot be classified as a tool for it provides no mechanical advantage since its distinguishing features are memory, access to memory, and arithmetic and logical power. Unlike tools, the structure of

computers allows communication with other computers as well as with their users. The use of a computer requires no particular motor skills, but rather skills of communication of ordered processes, processes which are at least today, developed to a large extent by humans. Thus, in communicating a set of ordered procedures or processes to the computer, the author must externalize his own thought processes into a communication. Parenthetically, a parallel may be drawn between the importance of natural language and computer language to the development of cognitive processes (Hart, 1978; Groen, 1978). The computer simply carries out these processes, providing not a mechanical advantage, but an advantage in calculation speed, accuracy, and fast access to memory. Clearly, in this context the computer is not a tool providing a mechanical advantage to the user, but rather a device providing a cognitive advantage, although bounded, to the user. But this capability, coupled with its capability for communication involving both symbolic and graphical representations, provides the user with the results of having his externalized thoughts simulated. These outputs in themselves help the user to identify conceptual inadequacies, to provide the basis for re-formulation and correction. It is for these reasons, that a computer is more correctly referred to as an amplifier of intelligence rather than a tool. However, amplifiers whether for light as made by lenses, or sound as in public address systems, only amplify what is given to them. Therefore, the computer can also be an amplifier of stupidity.

Because education traditionally has involved humans as teachers and learners, certain finite limits of capacity must be recognized. Learning by definition is taken to be learning by an organic system, a system defined by genetic and environmental factors. The only exception to

this is not one of possibility, but of our intent, for work is already slowly proceeding to have computers 'learn'. The computer has those system characteristics which have been specifically designed to overcome certain cognitive limitations of the human. If there is any device being created in the likeness of man, it is the computer. Because of its capabilities of communication, coupled with capability of simulating externalized thought process given to it as ordered sequences of procedures, the computer can take on a major role in education. Because of its speed, it can integrate the monitoring and instructional functions without degradation of either.

Communication, however, is a two-way street. The results of simulating externalized thought processes and communicating the results to the originator of such processes, can force the originator to reconsider his own thinking and to initiate a new cycle. When such communications do not result in a confirmation, or a reconsideration of thinking processes, we run the risk of amplifying and perpetuating errors.

Because theories of learning are weak, we must consider an additional component in the research, development, and dissemination paradigm. That additional component must be one of monitoring and feedback to the other basic elements. In the context of instruction, the same component which provides the monitoring can also be used to execute or simulate our externalized thought processes not only for the purposes of self instruction, but also for the instruction of others. We must, however, always keep in mind that human thought is most likely to continue to be considerably more unbounded than that of a finite computer.

As with most things in nature, a balance must be maintained not

only among opposing forces, but also among sympathetic forces. Clearly, man values his social interactions and especially those which enhance mutually pleasing experiences. Educators and teachers must never forget that although the development of technology to enhance our cognitive capacities will continue for sometime at an accelerating rate, the environment which this will create must be balanced by softer environments involving other creative human endeavors. Such an environment can be encouraged through the development of such activities as painting, pottery, sculpturing, not as a basis of economic livelihood, but rather as a retreat for the human creative and social spirit. In the context of education, as we are drawn into harder technological environments, we must never forget about the social capacities of compassion, empathy, and sensitivity to human needs. There will be no simulation for a loving hug to a young child. Such activities must always be enhanced in order to produce a world worth living in, for the human social capacity can range from the depths of bestiality to the heights of compassion and sacrifice for the needs of others.

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